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UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

MILLING METHODS AND COSTS AT THE MILL OF THE TOM REED GOLD MINES CO., OATMAN, ARIZ.

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BY

PARIS V. BROUGH

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MILLING METHODS AND COSTS AT THE MILL OF THE TOM REED GOLD MINES CO., OATMAN, ARIZ.[1]

By Paris V. Brough[2]

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[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 6975."

[2] One of the consulting engineers, Bureau of Mines, and former superintendent of Tom Reed mill.

INTRODUCTION

This paper, which describes the practice of milling custom ore, in addition to that produced under company and lease operations in the Tom Reed mines, is one of a series being prepared by the Bureau of Mines.

ACKNOWLEDGMENT

Acknowledgment is made to W. B. Phelps, managing director, and Jack Zwinge, superintendent, for permission to publish, and to G. E. Jarpe, the present mill superintendent, for his assistance in preparing the paper.

LOCATION

The mill is in Oatman, adjacent to the Benjamin Harrison shaft of the Tom Reed Gold Mines Co., in the foothills on the western slope of the Black Mountains, western Mohave County. The railroad shipping point is Kingman, Ariz., 25 miles northeast of Oatman. Paved highway U. S. 66 passes by the mill. The altitude is approximately 2,700 feet.

GENERAL

Sources of Ore

The mill treats ore mined on company account, that produced by lessees on company property, and custom lots from outside sources. The lease ore is treated on a custom basis.

Ore produced on company account is hoisted through the Benjamin Harrison and Black Eagle shafts; the latter shaft is approximately 1 mile to the southeast and connected to the mill by an aerial tramway. Most of the company lease ore is hoisted through shafts that are not being worked by the company and is trucked to the crushing-plant bins. An occasional lot of lease ore, however, is hoisted at the Black Eagle shaft and shipped via the aerial tramway. Most of the outside custom ore comes from the Oatman district within a radius of 10 miles and includes company lease production from the Gold Road Mine of the United States Smelting and Refining Co. (1936), and ore from the Ruth and Rattan claims of the Oatman Eastern Gold Mines Co. in the Silver Creek section, the Pioneer group 4 miles west of Oatman, and smaller quantities from many properties in the district. Ore also comes from various other sections within a radius of 100 miles, some coming from California and southern Nevada. All outside ore is trucked to the bins of the crushing plant.

Tom Reed ore is mined from shrinkage and cut-and-fill stopes; the method is governed by ore widths and wall-rock conditions rather than by metallurgical requirements. To date (April 1937), most of the mining since starting in 1934 has been done around the fringes of old stopes. Unwatering, cleaning out, and retimbering of both the Benjamin Harrison and Black Eagle mines has been proceeding since February 1934 for the purpose of developing the vein system below the old mined areas.

Tom Reed lease ore is mined under the supervision of a lease foreman, whose duty it is to enforce reasonably safe mining operations. Outside custom ore is mined by both open-cut and underground methods; many of the smaller leases are partnerships.

Character of Ore Treated

With the exception of occasional odd lots from distant districts and the Oatman Eastern production, the ore milled is characteristic of the Oatman District. The chief gangue minerals consist of quartz, calcite, silicified andesite from stringer lodes, quartz monzonite, and varying amounts of fluorspar, adularia, and oxides of iron.

The stringer lodes of the Black Eagle and Gold Road mines produce some very hard and tough ore, while the quartz calcite ore bodies of the district are of average hardness. Most of the ore produced by the Tom Reed, United Eastern, and Gold Road vein systems requires grinding to 85 percent or more through 200 mesh for a satisfactory recovery, as the gold occurs as very fine particles disseminated in the gangue. The ores originating elsewhere in the district are more free milling; the metallic particles are larger and occur chiefly in the parting planes. A satisfactory yield is obtained by grinding to 60 to 70 percent minus 200 mesh, providing the contact period in cyanide solution is 72 hours or more.

Oatman Eastern ore carries finely disseminated sulphides, reputedly arsenopyrite, with from 2 to 6 ounces of silver per ton in addition to gold. This ore requires small additions of lead acetate to the agitators as an aid to silver recovery and the prevention of matte formation in the melting of bullion. Occasional lots of silver-bearing ore from outside the district are milled, but with these exceptions mill feed carries gold and silver at a ratio of approximately one to one by weight.

Microscopic Examination

When characteristic Tom Reed, Gold Road, and Pioneer ores are milled alone, 95 percent or more of the gold and only about 50 percent of the silver is recovered. These recoveries indicate that all the silver was not alloyed with the gold and the probable presence of minute quantities of some silver mineral. Microscopic examinations have borne out this conclusion; both electrum, containing all of the gold and part of the silver, and native silver have been identified.

The following quotations are from reports of microscopic investigations of the Tom Reed tailings made by the American Cyanamid Co.[3] The earlier investigation was on tailing after about 60 hours agitation, and the latter one on tailings after 72 hours agitation on somewhat coarser ground ore. The May 12, 1936, report states:

3/ Microscopical Examination of a Tailing Sample Submitted by Tom Reed Gold Mines Co.; Technical Investigation 58, Experiment 947, May 12, 1936, and Experiment 1097, January 13, 1937.

Present Operations: The sample submitted was a washed tailing that had been composited from daily samples on the basis of tonnage treated during the month of February 1936. The sample was said to represent the tailing from 7,201 tons of ore, of which 3,600 tons were custom ores received from other mines in the district.

Purpose of Investigation: The purpose of this investigation was to determine the mode of occurrence of the gold and silver present in the tailing.

Preliminary Test Work. Preparation of Samples for Microscopical Investigation: The entire amount of material received was mixed thoroughly by rolling on a cloth; it was subsequently sampled by quartering.

Because of the small size of the sample, it was not possible to use any of the material for assay purposes.

A representative portion of the tailing weighing 500 grams was screen-sized. The plus 200-mesh screen products were reserved for microscopical examination. The minus 200-mesh material was concentrated on a vanning plaque and the concentrate was dried.

A second representative portion of the tailing as received was carefully concentrated on a vanning plaque and the concentrate was dried for subsequent examination.

The samples used for the microscopical examination were numbered as follows:

No. 1 Pan concentrate of tailing.
No. 2 Plus 100 mesh tailing.
No. 3 Plus 150 mesh tailing.
No. 4 Plus 200 mesh tailing.
No. 5 Pan concentrate of minus 200 mesh tailing.

Microscopical Examination: The microscopical examination of the samples was conducted by our Dr. P. L. Merritt.

A portion of each of the prepared samples was first molded into a briquette of bakelite by means of a heated, hydraulic press. The briquettes were then polished to a plane surface on a Graton-Vanderwilt automatic polishing machine.

As a result, the individual grains of tailing material were presented in cross section and it was possible to examine them with reflected light. The relationship between the metallic minerals and the gangue minerals was readily observable.

Similar portions of each prepared sample were reserved for examination of the unmounted grains by means of transmitted light.

The investigation showed that pyrite was the principal sulphide mineral and that some chalcopyrite also was present. Hematite was the most abundant metallic oxide mineral. The gangue minerals were largely quartz and chert, but carbonates also were present.

The gold present in the tailing was found to occur only as the natural gold-silver alloy, electrum. Silver, however, was also found to occur in the metallic state.

Dr. Merritt's observations of the various samples, together with suitable photomicrographs, follow.

Sample 1. - Panned Concentrate of the Tailing: Pyrite and a small amount of chalcopyrite were found in this sample. Electrum and native silver were observed. Most of the electrum was free; the particle size of the electrum was from 12 x 34 microns to 25 x 50 microns. However, one particle of electrum, 30 x 30 microns in size, was observed, which was attached to pyrite. Another particle was noted which was surrounded by hematite.

Sample 2. - Plus 100 mesh Screen Product: The examination of this product showed that free silver and electrum, as well as locked particles of these, were present. One particle of electrum, 15 x 15 microns in size, was found attached to a particle of gangue mineral.

Sample 3. - Plus 150 mesh Screen Product: This sample was essentially like the plus 100 mesh sample. A particle of free electrum was noted that measured approximately 40 x 50 microns.

Sample 4. - Plus 200 mesh Screen Product: This sample did not differ greatly from the previous screen products. It did contain a little more chalcopyrite. The occurrence of native silver and electrum also was observed. This sample contained a free particle of electrum that measured 10 x 35 microns in size.

Sample 5. - Pan Concentrate of minus 200 mesh Screen Product: Since this was a concentrated sample, the briquetted portion showed a greater number of metallic minerals than the other samples.

Pyrite and chalcopyrite were present together with native silver and electrum.

The native silver was free for the most part. A few particles were observed attached to gangue.

The electrum particles were largely free from all attachment. The particles were from about 5 x 10 to 20 x 110 microns in size.

Summary and Conclusions: A sample of cyanide tailing containing 0.021 ounce per ton gold was investigated for the Tom Reed Gold Mines Co. The results of this investigation may be summarized as follows:

1. Screen-sized portions of the tailing as well as a pan concentrate of the total tailing and a pan concentrate of the minus 200 mesh tailing were examined.
2. The gold was found to occur in all samples as the natural gold-silver alloy, electrum.
3. Silver was found to be present in the native state as well as in the alloy.
4. The electrum and native silver were largely free from mineral attachment. Occasional particles of electrum were found attached to hematite, pyrite, or gangue.
5. The greater number of electrum particles noted were less than 325-mesh sizes; a few particles observed were +150 mesh size. It has been shown that the particle size range of electrum and silver was from 5 to 110 microns. (Five microns is equivalent to a theoretical screen opening of about 2,000 mesh, and 110 microns is approximately equivalent to 150 mesh).

The fact that a majority of the gold-bearing electrum particles are free or substantially free from mineral attachment makes it appear that finer grinding alone will not result in better extraction of the values. Since the gold occurs only in association with silver, it would appear that an effort should be made to determine the effect of time of contact, alkalinity, and cyanide strength on the recovery of additional values from this tailing.

The tests shown in the January 13, 1937, report were made after another large agitator and new thickener had been added to the mill. The samples consisted of the composite mill tailing, a panned concentrate of the composite mill tailings, and a panned concentrate of minus 200 mesh composite tailing. A separate portion of the tailing, as received, was examined under the petrographic microscope for the purpose of identifying the transparent mineral constituents.

Microscopical Examination:

A. Composite Mill Tailing

The following metallic constituents were identified:

Hematite
Pyrite
Sphalerite
Chalcopyrite
Electrum
Native silver

The transparent minerals identified were as follows:

Quartz
Chert
Carbonate

Although most of the metallic constituents apparently were free from the transparent constituents, some were still locked.

The gold values occurred in the form of the gold-silver alloy electrum. Silver values were present both as electrum and as native silver.

Electrum occurred both as apparently free grains and as particles of micron size, which were locked with the transparent gangue minerals.

The free metallic constituents were panned out of a portion of the original composite tailing. The resulting clean sand tailing was then reground so as to pass through a 325-mesh screen. The reground product was then panned on the Haultain mechanical panner and the metallic concentrate was examined microscopically. Grains of metallic constituents, including electrum, were observed in the panned concentrate; evidently they had been freed during the extra grinding operation.

B. Panned Concentrate of Composite Mill Tailing

The following metallic constituents were observed:

Hematite
Pyrite
Sphalerite
Chalcopyrite
Electrum
Native silver

The only gold values observed were in the form of apparently free grains of electrum. No electrum was observed to be locked with the metallic constituents.

The size of the free grains of electrum ranged from 4 x 15 microns (approximately 3,700 mesh) to 30 x 60 microns (approximately 500 mesh).

C. Panned Concentrate of Minus 200-Mesh Composite Tailing

The following metallic constituents were identified:

Hematite
Pyrite
Sphalerite
Chalcopyrite
Electrum
Native silver

The electrum, which was observed, occurred as apparently free grains, which were within the same size range as those present in the panned concentrate of the composite mill tailing.

Conclusions:

1. Hematite, pyrite, sphalerite, chalcopyrite, electrum, and native silver were the metallic constituents identified in the tailing. The chief transparent gangue minerals were quartz, chert, and carbonate.
2. The gold values were in the form of gold-silver alloy electrum, some of which was free.
3. The silver values were present both as native silver and as the gold-silver alloy electrum.
4. Apparently free grains of electrum, ranging in size from approximately 3,700 mesh to approximately 500 mesh, were observed.
5. According to the assays furnished by the subject company, the composite mill tailing assayed 0.0183 ounce, or $0.64 per ton in gold. Both the minus 200 mesh sand and slime assayed 0.01 ounce, or $0.35 per ton in gold.

   In view of the fact that the minus 200 mesh material assayed $0.35 per ton in contrast to an assay of $0.64 in gold in the composite tailing, it would appear that finer grinding should reduce materially the gold content of the final tailing.

That finer grinding should improve the recovery of gold is substantiated by the fact that electrum was panned out of the reground clean sand. Moreover, particles of electrum of micron size were observed as inclusions in the transparent gangue minerals.

CUSTOM-MILL SCHEDULES

The following, quoted from posted notices, are the schedules of milling rates and basis of settlement under which custom ore is received at the mill of the Tom Reed Gold Mines Co.

Settlements on all custom and lease ores will be made trimonthly on all completed assays on the 5th, 15th, and 25th of each month. Checks should reach Oatman on or about the 8th, 18th, and 28th of each month.

Settlements on gold at $35 per ounce.

Settlements on silver at domestic price.

The following schedule regarding custom ore rates became effective February 15, 1934:

For 35 tons daily lot shipments or more. Regular daily shipment schedule.

Milling rate $3.60 per ton will pay 95 percent of the gold content.

- - - - - -

For 25 ton daily lot shipments to 35 tons.
Regular daily shipment schedule.

Milling rate $3.80 per ton will pay for 95 percent of the gold content.

- - - - - -

For 25 ton or more individual lot shipments.
Irregular shipment schedule.

Milling rate $4 per ton will pay for 95 percent of the gold content.

For less than 25 ton individual lot shipment.
Irregular shipment schedule.

Milling rate $4.50 per ton will pay for 92 percent of the gold content.

- - - - - -

For lots less than ten tons a flat extra charge of $10 will be added for sampling and assaying.

The above schedule is subject to revision on 20 days' notice. A shipper will be considered in the daily lot shipment class when he ships at least three or more consecutive shipments. Lessee royalties will remain the same, but the above schedule applies to lessees' ores.

TOM REED GOLD MINES CO.

Oatman, Ariz., March 12, 1935.

ORE SCHEDULE RATE

The following reductions over the old, or base rate of $3.60 per ton, is herewith submitted:

For a daily average tonnage covering a period of one month:

Plus 30 tons to 50 tons per day......	$3.50	per ton
Plus 50 tons to 70 tons per day......	3.45	per ton
Plus 70 tons per day.................	3.40	per ton

We will pay 95 percent of the gold content, provided our plant, as normally operated, can make this recovery.

These rates are based on present commodity, labor, and power prices. Thirty days' notice will be given by the Tom Reed Gold Mines Co. in case of an advance in the cost of these items and a change of milling rates.

Our rate changes will be calculated solely upon the advance of labor, supplies, or power.

If for any reason, such as failure of equipment or repairs to same, we are unable to receive ore from a shipper in this class, the shipper will not be penalized for a shortage of tonnage at the end of the settlement period.

TOM REED GOLD MINES CO.

November 9th, 1935

Milling rates and conditions pertaining to the custom milling of ore concentrates and high grade ores suitable for our mill

Concentrates and ores will be classified as high grade when the assay value is greater than four ounces of gold per ton, and ten ounces is the maximum we will receive.

Individual shipments of such products will be limited to a maximum of 15 tons and the moisture content must not exceed 4 percent.

Milling rate $4.50 per ton.

Payment will be made on 92 percent of the gold content.

Silver content will be disregarded on irregular shipments.

Due to the extra hazard of salting, in running such material through the bins and sampling mill, an extra charge of $10.00 per lot will be made, to cover the expense of extraordinary cleaning up of equipment.

TOM REED GOLD MINES CO.

LOW-GRADE ORE SETTLEMENT SCHEDULE

Commencing April 1, 1936, the extraction deductions on free milling ores, regardless of tonnage, will be made as follows:

Grade of ore	Extraction deduction
0.23 oz. au. ($8.05) or more	5 percent
0.17 oz. au. ($5.95) to 0.23 oz	8 percent
Under 0.17 oz. au	10 percent

Tailing requiring regrinding and refractory ores will be subject to separate consideration.

Settlements for silver content will be subject to separate consideration as to grade, tonnage, and the results of small-scale test work.

SAMPLING AND ASSAYING OF LESSEES AND OUTSIDE CUSTOM ORES

Control sample

Original and duplicate control sample to both buyer and seller in sealed envelopes.

- - - - - -

For the purpose of checking, both buyer and seller will run control sample designated as "original". If difference between these results does not exceed 0.02 ounce per ton, settlement will be made on split.

- - - - - -

Umpire

If the difference between results of buyers' and sellers' assays is such that either buyer or seller may object to settlement thereon, the sample for umpire (which has been placed in sealed envelopein Tom Reed vault) shall be sent to some reputable and recognized umpire assayer mutually agreed upon by buyer and seller.

- - - - - -

Settlement basis

Settlement basis shall be on either buyer's or seller's assay showing returns closest to the umpire's results.

HISTORY

Operations on the Tom Reed vein began in 1904. About 1906 a 10-stamp mill was built. Recovery was made by inside and apron-plate amalgamation followed by sand leaching in vats, the slime being impounded without treatment. In 1908 a new 20-stamp mill with a capacity of about 125 tons daily was built; the process adopted was all-slime batch treatment followed by Butters-type filtration and washing. Flint pebble mills were used for secondary grinding, as the first mill had demonstrated that finer grinding was necessary. Cones were used for classification. Thickening also was accomplished with cones of larger diameter, which discharged to Pachuca-type agitators. Precipitation was by zinc shavings. Plates were installed in this new mill but amalgamation was soon discarded, as amalgamation recovery was reported to have been only 50 to 60 percent.

About 1912 a Dorr primary thickener was installed, and in 1913 or 1914 the first Dorr counter-current decantation plant was added, and the Pachuca agitators were put in series. This latter practice was not satisfactory, for colloidal accumulations formed, which seriously reduced the active area. After these changes, the Butters filter was used only for clarification of solution. About 1915 one Merrill zinc-dust precipitation press was installed in parallel with the zinc boxes.

In 1917, after the discovery of the Aztec ore body, Allis-Chalmers ball mills of about 200 tons daily capacity were installed for primary and secondary grinding. Stamp milling was discarded, except in emergencies. At this time additions to the treatment plant were made by installing one 40- by 12-foot primary thickener, four 40- by 12-foot agitators, and five 28- by 12-foot decantation thickeners in parallel with the early installation. This was all Dorr equipment. Zinc-shaving precipitation was discontinued and a second press was added.

Company operation of the mine and mill ceased in 1924, at which time leasers took over both with the intention of mining pillars and arches left in the mine. During the leasing period the mill was operated on reduced tonnage and some of the decantation plant was dismantled, and the fourth agitator was converted into a tailing thickener. Lease operation was intermittant until January 1930.

Reduced tonnage company operations were resumed about January 1, 1930, as development work had opened up the Black Eagle ore body. This operation continued until February 1932, at which time the mill was shut down.

The $35 an ounce price of gold aroused new interest in the district, and the Tom Reed Gold Mines Co. decided to start the mill on a custom basis in addition to milling their own product. The company mines were in such condition that little production could be expected from them for some time. In order to encourage the custom ore business, an attractive schedule of milling rates and bases of settlement was posted, which, with but few modifications, is still in effect.

The mill was started in February 1934 on a one-shift grinding basis. The custom business grew fast, and by June of that year it became necessary to replace some abandoned thickeners. Facilities for receiving custom ore were very poor, so three hopper-bottomed steel bins, with accessory equipment, and a Merrick weightometer were installed. The latter eliminated the necessity of estimating Black Eagle and Ben Harrison tonnages and weighing ore hauled by truck on platform scales. Several improvements were made in the sampling mill also.

Early in 1936 a new ball-mill unit went into service and was followed by further additions and alterations to the treatment plant, which now (April 1937) usually operates up to the settling capacity of the thickeners. The additions and alterations have been justified by satisfactory reduction in costs as well as a material increase in tonnage with but little sacrifice in recovery.

MILLING

The mill (1937) is an all-slime cyanide plant embodying single-stage crushing, ball-mill grinding, agitation, and counter-current decantation. A daily capacity of 290 tons is obtained under current grinding practice.

Water for milling purposes is pumped from the mines, there having been an excess up to the present time.

Crushing

Ore from the Benjamin Harrison Mine and lease ore is crushed at the main crushing plant adjoining the mill. A crushing plant at the Black Eagle shaft handles ore from that mine. Run of mine ore up to 10 and 12 inch is received at both crushing plants.

The mill crushing plant was built in 1908 and had an initial capacity of 125 tons; since that time several changes have been made. The crushing-plant site is poorly adapted for modernizing the plant with screens or grizzlies. There is a fair location, however, for a secondary crushing unit, with accessories, between the present crushing plant and the sampling mill, if future developments justify the expenditure.

The Black Eagle plant was built in 1929, but no provision was made for grizzlies, screens, or sorting. Plans are now being considered for installing a grizzly and sorting belt ahead of this crusher.

The Black Eagle tramway loading terminal is approximately 5,000 feet from and 257 feet higher than the discharge terminal at the Benjamin Harrison crushing plant. Bucket speed is governed by a 30-horsepower alternating current motor through belts.

Tom Reed company production from the Benjamin Harrison and Black Eagle shafts is weighed and sampled separately, as carefully as is all custom and company lease ore. Black Eagle crushing plant costs are recorded, the plant being so far from the mill, but these charges are included in the total milling costs. Benjamin Harrison crushing costs are not available, as crushing and milling are carried on as a single operation.

The capacity of the Ben Harrison crushing plant is sufficient to crush the ore for a days' run of the treatment plant on one shift. It is operated, however, two shifts daily, day and afternoon, as (1) custom ore, being hauled in trucks, is frequently delivered over an 8-hour period and bins must be emptied for another shipper on the following morning; (2) the mill bins do not have sufficient live storage satisfactorily to supply the treatment plant for 16 hours without shoveling.

Crushing on one shift would require constant operation during the period, while the two-shift scheme permits time for proper cleaning up between runs, lubrication, and minor repairs to equipment; these duties are performed by the operating crew. The custom business necessitates the employment of a larger crushing-plant crew than would be required in the milling of company ore only. In order to avoid confusion in running and sampling the separate ores, a foreman is employed on each shift and receives his instructions direct from the mill superintendent.

The milling characteristics of ores, even from the Tom Reed and Gold Road vein systems, vary considerably. In order to work to the best advantage, ores of similar nature are crushed consecutively as far as possible and are delivered to bins feeding to both primary grinding units. When a change of ore reaches the mill bins, the crushing-plant foreman informs the ball-mill operator, who makes the necessary adjustments relative to classifier solids to be carried until the next change of ore. Crushing plant flowsheet is shown in figure 1. The crushing rate of the Benjamin Harrison plant is 40 to 45 tons per hour, which is the normal capacity of the conveyor belts and the weightometer. It is equipped with a 12-inch Traylor type R crusher.

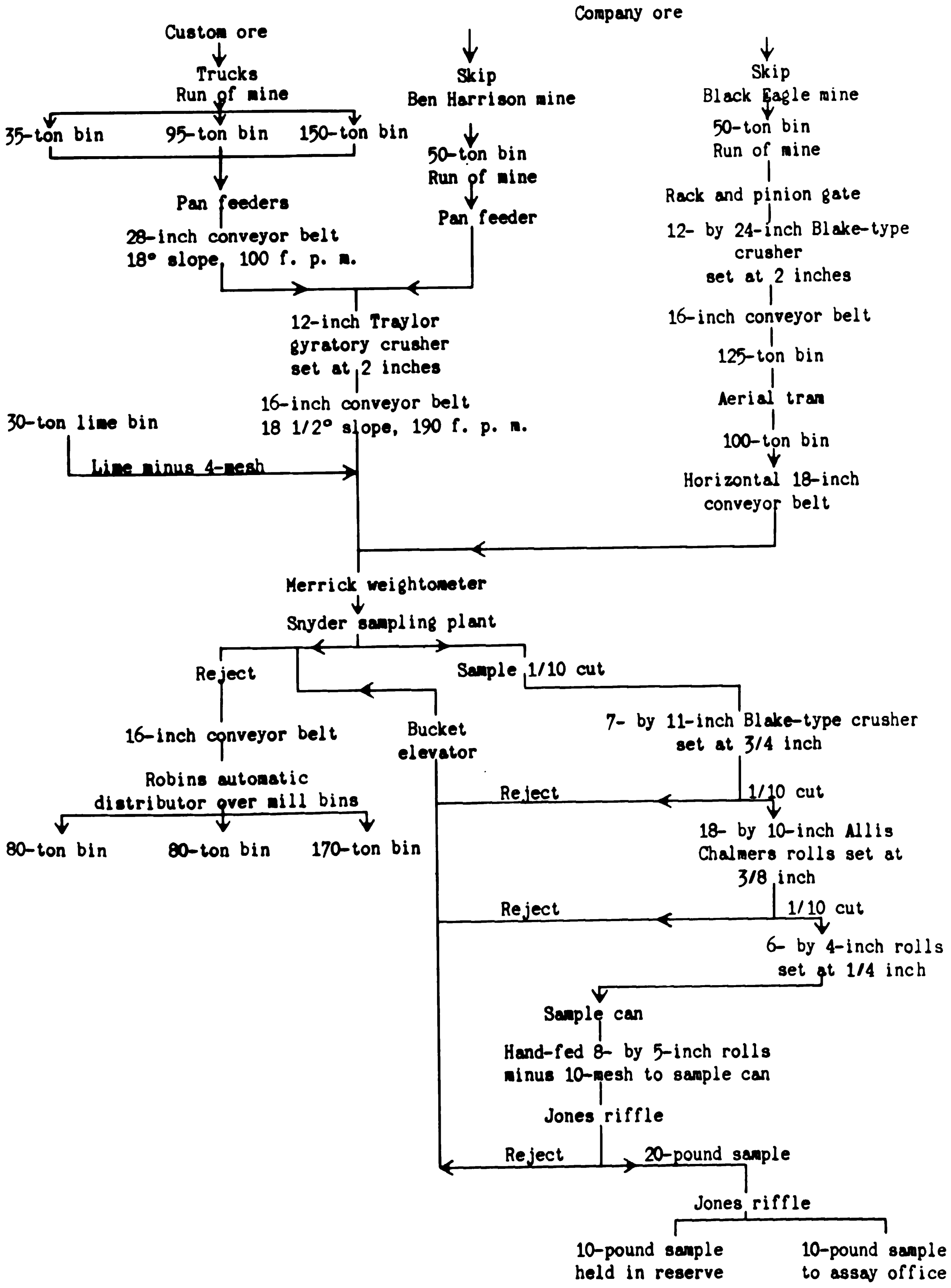

Figure 1.- Flow sheet, crushing plants, Tom Reed Gold Mines Co.

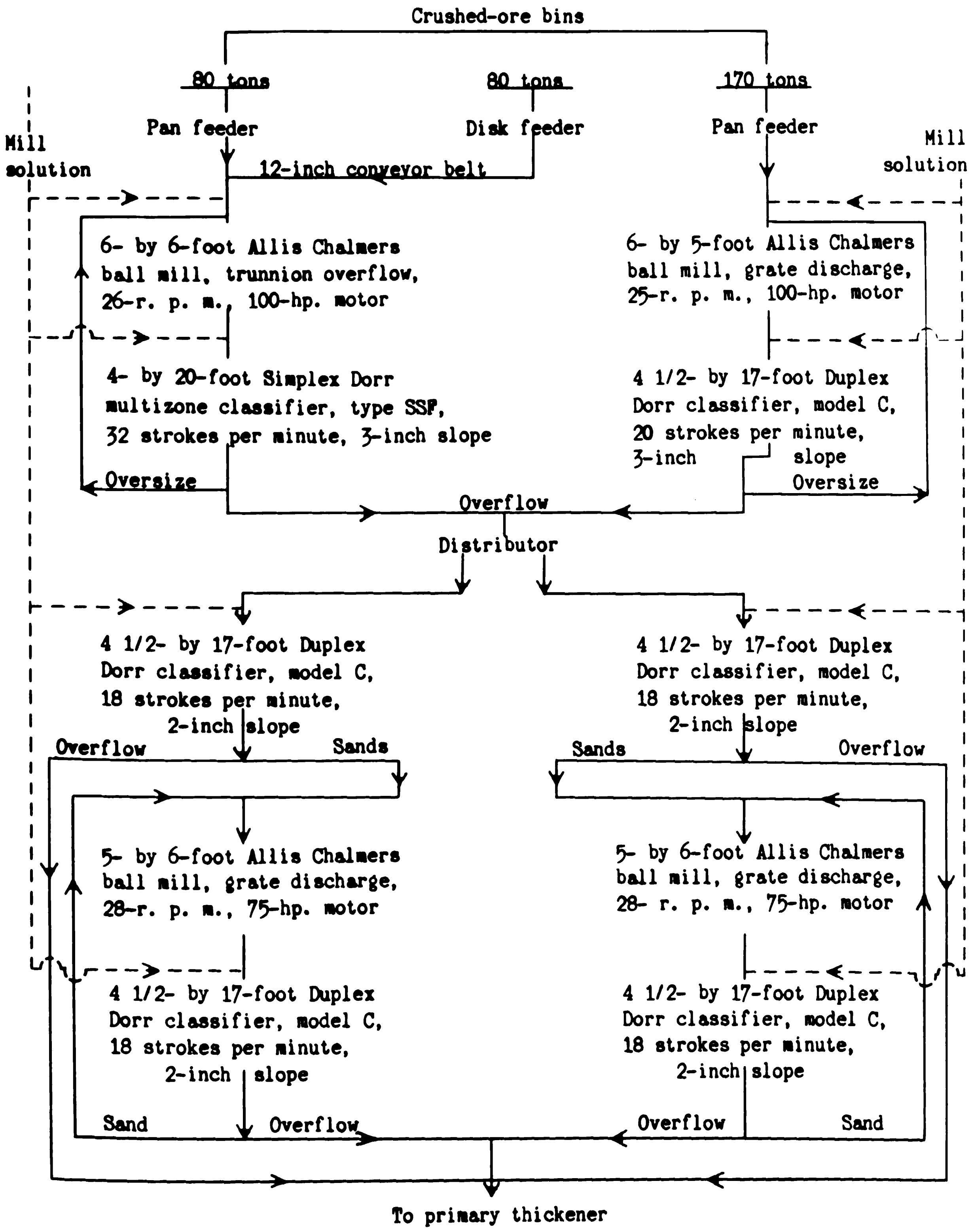
Crushed-ore bins
80 tons
80 tons
170 tons
Pan feeder
Disk feeder
Pan feeder
Mill solution
Mill solution
12-inch conveyor belt
6- by 6-foot Allis Chalmers ball mill, trunnion overflow, 26-r. p. m., 100-hp. motor
6- by 5-foot Allis Chalmers ball mill, grate discharge, 25-r. p. m., 100-hp. motor
4- by 20-foot Simplex Dorr multizone classifier, type SSF, 32 strokes per minute, 3-inch slope
4 1/2- by 17-foot Duplex Dorr classifier, model C, 20 strokes per minute, 3-inch slope
Oversize
Oversize
Overflow
Distributor
4 1/2- by 17-foot Duplex Dorr classifier, model C, 18 strokes per minute, 2-inch slope
4 1/2- by 17-foot Duplex Dorr classifier, model C, 18 strokes per minute, 2-inch slope
Overflow
Sands
Sands
Overflow
5- by 6-foot Allis Chalmers ball mill, grate discharge, 28-r. p. m., 75-hp. motor
5- by 6-foot Allis Chalmers ball mill, grate discharge, 28- r. p. m., 75-hp. motor
4 1/2- by 17-foot Duplex Dorr classifier, model C, 18 strokes per minute, 2-inch slope
4 1/2- by 17-foot Duplex Dorr classifier, model C, 18 strokes per minute, 2-inch slope
Sand
Overflow
Overflow
Sand
To primary thickener

Figure 2.- Grinding circuit, Tom Reed mill.

In order to maintain a fairly uniform feed size to the ball mills, with one stage crushing, two crusher shafts and three mantles are used; they are changed frequently. The mantles have different diameters and each one is built up to its respective dimension with hard surfacing, in the shop, after removal from the crusher. With this system, lower concaves are worn to holes with only one resetting. Shaft and mantle changes are made in a short time, while concave resetting requires a seriour loss of crusher time.

One-stage crushing is practiced at the Black Eagle plant also. An Allis-Chalmers, 12- by 24-inch, Blake-type crusher is used. It is equipped with nonchoking type swing jaw plates in order to minimize the amount of oversize and extend the life of jaw plates. These plates are also built up with hard surfacing when worn. The crushing rate is about 20 tons per hour.

A flat belt drive, slack enough to throw if tramp steel gets into the crusher, is used at the Benjamin Harrison plant. The Black Eagle crusher is driven through texrope belts, the toggles of the crusher being the safety factor for tramp iron.

Grinding

Two-stage grinding is practiced. The primary grinding unit consists of two ball mills; the first is a 6- by 6-foot trunnion overflow mill equipped with a heavy manganese-steel slotted grid cast integral with the discharge-end throat liners and shiplap-type shell liners. Manganese-steel liners are used throughout. This ball mill, installed in 1936, is direct-driven through a Weust gear and pinion with offset apex feature for reduction of vibration. The second is a 6- by 5-foot grate-discharge ball mill with shiplap-type shell liners and tool-steel bar-grate sections; the liners are manganese steel. It was installed in 1917 and is driven through a Weust gear and pinion with center apex.

The secondary grinding stage consists of two 5- by 6-foot grate-discharge mills of like design. They are equipped with manganese-steel, wave-type shell liners and cast tool-steel grate sections, and are direct driven through Weust gear and pinion with center apex. They were installed in 1917.

The flow sheet of the grinding circuit is shown in figure 2. All grinding is done in cyanide solution; the solids in the primary mills are maintained at approximately 72 percent and in the secondary mills at about 63 percent. The primary mills are operated in parallel most of the time, the only exceptions being when there is a shortage of ore or when milling an ore that requires exceptionally fine grinding. More efficient grinding is obtained when all four mills are operated, for at such times higher circulating loads can be carried. When only one primary mill is operating, it is usually operated in open circuit, at higher than average solids, as a guard against severe pounding of the liners. This practice results in a coarser feed to the secondary mills but keeps them well loaded.

Solids in the primary classifiers are subject to wide variations as ore changes occur. Solids in the intermediate classifiers are adjusted to correspond to the closed-circuit secondary machines. Frequent solid changes are made at these points as fine or coarse grinding is desired. Fine or coarse grinding practice at this mill is only comparative, as the average grind is nearly all through 100 mesh.

There is no standard practice concerning circulating loads in the primary circuits, as ore changes occur frequently. Full rakes are always carried on the secondary classifiers, this load being approximately 2-1/2 to 1, which is the limit for these machines at current speed. Intermediate and secondary classifier solids vary from 7-1/2 to 13 percent, this flow being the primary thickener feed.

Settling area in the primary thickener at 290 tons a day is 4.33 square feet per ton. Average specific gravity of mill feed is 2.7.

Typical screen sizings of the grinding circuit feed and products are illustrated in table 1.

TABLE 1. – Screen sizes, grinding circuit products, October 1936

Screen	Grinding		Primary classifier				Intermediate classifiers		Secondary classifiers	
	Feed, primary1/ Nos. 1 and 2	Feed, secondary1/ Nos. 3 and 4	No. 1 unit		No. 2 unit					
	Percent	Percent	Feed, Percent	Overflow, Percent	Feed, Percent	Overflow, Percent	Feed, Percent	Overflow, Percent	Feed, Percent	Overflow, Percent
+3-inch ring	0									
-3 do. +2 do.	2.50									
-2 do. +1 do.	21.64									
-1 do. +1/2 do.	23.62									
-1/2 do. +3 mesh	18.34									
-3 do. +4 do.	4.07									
-4 do. +6 do.	5.06		1.96		3.13					
-6 do. +10 do.	6.36		2.85	3.86	6.21	2.21	3.03			
-10 do. +14 do.	3.99	0.84	5.15		10.94					

1/ Screen sizes, as shown on primary and secondary mill feed, is initial feed only and does not include classifier sand returns

TABLE 1. - Screen sizes, grinding circuit products, October 1936 (Cont'd.)

Screen	Grinding		Primary classifier				Intermediate classifiers		Secondary classifiers	
	Feed, primary1/ Nos. 1 and 2	Feed, secondary1/ Nos. 3 and 4	No. 1 unit		No. 2 unit					
	Percent	Percent	Feed, Percent	Overflow, Percent	Feed, Percent	Overflow, Percent	Feed, Percent	Overflow, Percent	Feed, Percent	Overflow, Percent
-14 do. +20 do.	2.54	3.52	7.79	6.00	14.19	5.67	5.84			
-20 do. +28 do.	2.19	9.71	11.18		13.22					
-28 do. +35 do.	1.89	15.10	11.72		10.71				3.00	
-35 do. +48 do.	1.63	19.09	10.98	15.05	8.15	16.44	15.75		9.43	
-48 do. +65 do.	1.14	19.09	7.99	19.14	7.18	22.18	20.66		20.66	
-65 do. +100 do.	1.11	13.79	9.28	7.78	5.93	5.27	6.52	5.67	26.46	5.67
-100 do. +150 do.	.77	8.30	6.50	7.68	3.36	7.37	7.53	10.48	14.29	10.48
-150 do. +200 do.	1.04	6.57	7.05	7.68	5.01	7.98	7.83	16.59	11.24	16.59
-200 do.	2.19	3.99	17.55	32.76	11.97	32.88	32.84	67.26	14.92	67.26

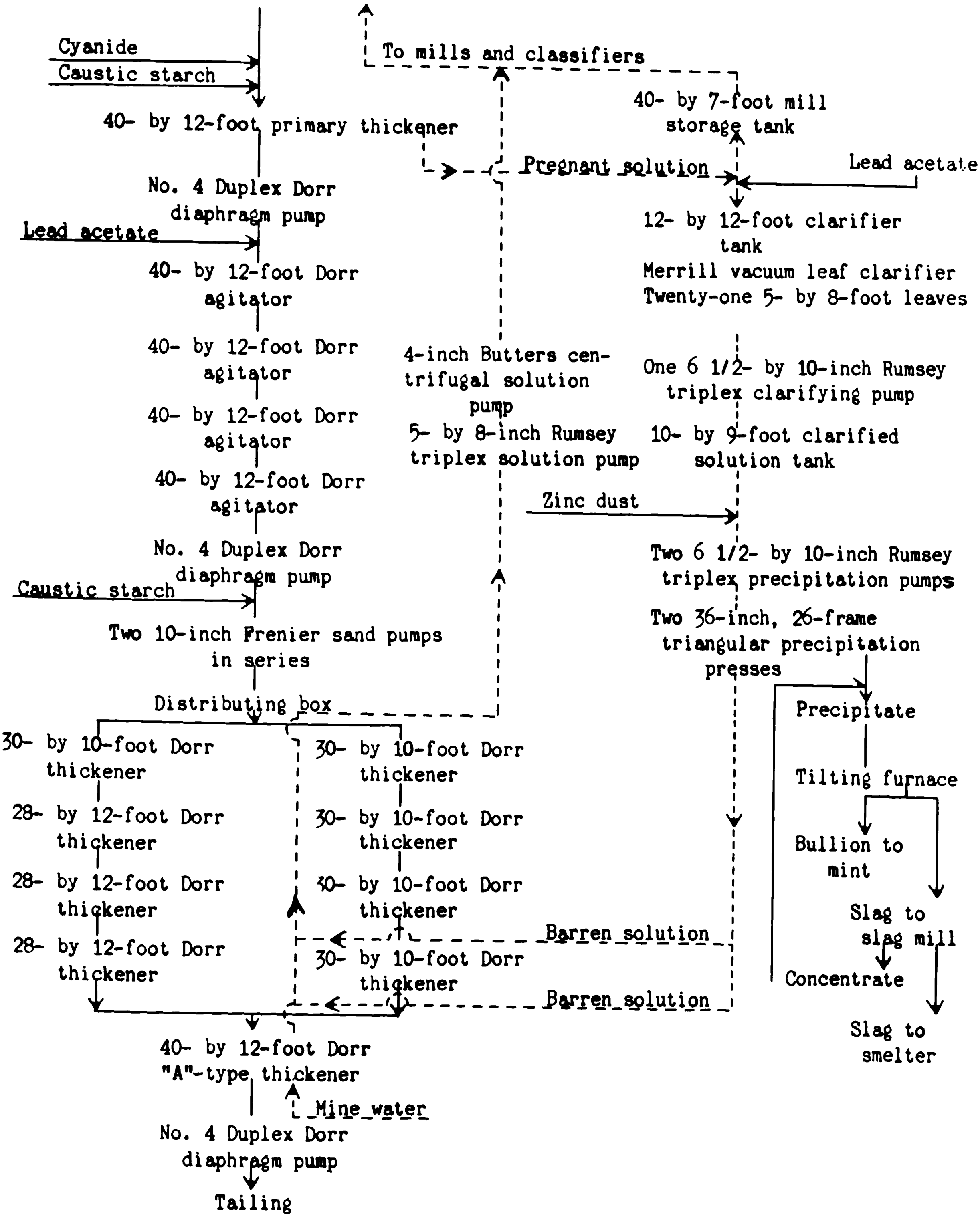
Cyanide
Caustic starch
40- by 12-foot primary thickener
No. 4 Duplex Dorr diaphragm pump
Lead acetate
40- by 12-foot Dorr agitator
40- by 12-foot Dorr agitator
40- by 12-foot Dorr agitator
40- by 12-foot Dorr agitator
No. 4 Duplex Dorr diaphragm pump
Caustic starch
Two 10-inch Frenier sand pumps in series
Distributing box
30- by 10-foot Dorr thickener
28- by 12-foot Dorr thickener
28- by 12-foot Dorr thickener
28- by 12-foot Dorr thickener
30- by 10-foot Dorr thickener
30- by 10-foot Dorr thickener
30- by 10-foot Dorr thickener
30- by 10-foot Dorr thickener
40- by 12-foot Dorr "A"-type thickener
Mine water
No. 4 Duplex Dorr diaphragm pump
Tailing
To mills and classifiers
Pregnant solution
4-inch Butters centrifugal solution pump
5- by 8-inch Rumsey triplex solution pump
40- by 7-foot mill storage tank
Lead acetate
12- by 12-foot clarifier tank
Merrill vacuum leaf clarifier
Twenty-one 5- by 8-foot leaves
One 6 1/2- by 10-inch Rumsey triplex clarifying pump
10- by 9-foot clarified solution tank
Zinc dust
Two 6 1/2- by 10-inch Rumsey triplex precipitation pumps
Two 36-inch, 26-frame triangular precipitation presses
Precipitate
Tilting furnace
Bullion to mint
Slag to slag mill
Concentrate
Slag to smelter
Barren solution
Barren solution

Figure 3.- Flow sheet of treatment plant, 1936, Tom Reed mill. Capacity, 290 tons.

Cyanidation

The flow sheet of the treatment plant is shown in figure 3. The underflow from the primary thickener is maintained at approximately 40 percent solids, except when a poor settling feed is on. This thickener will not function satisfactorily for any length of time with a higher percentage of solids, as island trouble develops or the slime line rises to the surface. Lime is added to the mill bins at a rate that maintains an alkalinity of about 1 pound of CaO per ton of solution in the primary thickener. This strength drops to 0.4 pound in the tailing thickener, but is sufficient to promote settling at that point. Caustic starch solution prepared at the mill is added to the primary thickener feed and at the head of the decantation plant when needed, these two points being most subject to muddy overflows.

No. 4 simplex Dorr diaphragm pumps serve the eight small thickeners and duplex pumps serve at other points. Solids in the decantation plant are carried at 45 to 50 percent, except the tailing, which is carried at about 54 percent in summer and 52 percent in winter.

Cyanide strength has been varied from 1.5 pounds to 2.5 pounds per ton of solution in the primary agitator, without any noticeable effect on gold recovery. The lower strengths of cyanide are not conducive to barren precipitation tail solutions, particularly in cold weather. Current practice calls for all additions of cyanide to be made to the primary thickener and maintaining the grinding and precipitation circuits at 2.2 pounds per ton. Lack of de-aeration equipment is probably responsible for the need for such strong solutions.

The grinding circuit and primary thickener account for a recovery of 65 to 70 percent of the gold. Assays for silver are made only on the monthly tail composite and bullion.

Clarification and Precipitation

Pregnant solution flows by gravity to the clarifier tank, in which twenty-one 5- by 8-foot Butters-type leaves, furnished by the Merrill Co., are suspended. This equipment was installed in 1935 to take the place of an old Merrill plate and frame sluicing clarifier of insufficient capacity. The leaf header is connected to the suction of an 8- by 10-inch Rumsey triplex pump, which discharges to the clarified gold tank. In spite of slime-flocculating reagents, the leaves soon collect a hard cake about 1/4-inch thick and it is necessary to clean and replace three or four leaves daily. The filter cake assays up to $9 per ton and is dumped into the primary agitator, it having been demonstrated in the laboratory that the pieces disintegrate and release the values after agitation.

The leaves are scrubbed with weak acid after being cleaned and are submerged immediately in a precoating tank, which is kept full of clarified solution. The alkaline solution neutralizes any residual acid. Three pounds of Hy-flo Supercell, a Johns-Manville product, are emulsified in water and dumped in the tank with each two leaves. Air jets below the leaves keep the Supercell in suspension while it coats the leaves.

The leaves are connected to the suction header and the vacuum is applied, while the tank is kept full with a stream of solution. The coated leaves are then returned to the clarifier tank. One No. 10 double-filled canvas filter bag is used on each leaf. Several modifications were made in the leaf construction after comparatively short service. The life of the bags is about 3 months.

There being no de-aerating equipment, pregnant solution flows by gravity to the precipitation pump. Zinc dust is added to the pump suction. The mixture is pumped about 200 feet to the precipitate presses. A drip of lead acetate solution is added to the clarifier tank. Except for occasional short periods, press tails are generally practically barren. This latter condition is essential, due to the fact that the barren solution is returned to the circuit as wash solution in the two thickeners preceding the one that discharges tailing. When there is doubt about press tail values, and until assays are obtained on press tail grab samples after cutting in a clean press, the press tail solution is diverted to the third pair of decantation tanks as a guard against enriching the mill tailing solution.

Filter media in the precipitate presses consists of one thickness of no. 10 double-filled canvas covered with one thickness of no. 230 Reeve-Angel filter paper. Canvases are acid-treated each month and have a life of 3 months. The paper is precoated with Hy-flo Supercell, added to the pump suction, and the press is cut in. This is repeated at times when the precipitate cake is sloughed. The Super-cell is figured as silicious flux in the melting process.

Barren solution is metered with a no. 5 Latham solution meter. Precipitation heads and tails are drip-sampled, and a meter reading is taken for each shift at the time samples are collected. The head solution is assayed daily for silver and gold. The silver content varies considerably from time to time, so the silver assay is used as a guide of the rate for feeding for zinc dust. Precipitation tonnage rate is varied from day to day, in an effort to maintain fairly uniform solution values throughout the plant, particularly in gold. Due to custom milling, there is no control over mill heads and a uniform precipitation tonnage rate cannot be set. The average rate is under 3 tons of solution for each ton of ore milled.

Clean-up procedure is as follows: The press to be cleaned is cut out and blown with compressed air to about 50 percent moisture, while a normal precipitation rate continues with the other press. Upon opening the press, most of the precipitate can be scraped from the frames or shaken off the filter paper. The papers are rolled up and then sprinkled with oil, without being dried, and ignited. The residual ash is added to the moist precipitate; the mixture is fluxed and charged to the melting furnace. The furnace is oil fired and takes a no. 150 graphite crucible. Crucible life is approximately 40 firing hours.

The flux is varied slightly, from time to time, but is approximately as follows:

	Percent
Borax glass	43
Sodium carbonate	32
Silica	20
Manganese dioxide	6.5
KNO3	Some occasionally
Previous slag shell	Variable

Thirty-three pounds of flux is used for 100 pounds of precipitate.

If sulphur fumes are present in the furnace gas, a wrought iron pipe is inserted in the melt after the charge is fused. Bullion bars will average about 875 in fineness with a single melt. Each bar is drilled from top to bottom, the drillings being assayed, after which the bar is shipped to the mint. The gold-silver ratio of bars varies over a wide range.

Tailings Disposal

The prevailing climate being arid, advantage is taken of the high evaporation rate, and tailing is impounded with a minimum of trestle and launder construction. Fresh water is added to the tailing to carry it out over the surfaces of the ponds. Light spiral pipe carries the tailing to the edge of but well above the top of the pond in service. The stream is deflected consecutively to one side or the other or to the center of the pond, as conditions justify. A fresh curb is hoed up around the edge of a pond as the tailing compacts; the ditch left by hoeing then serves as a launder when the stream is turned in.

Insets are made at 2-foot vertical intervals, the resulting shelf being used as a walkway until the next inset is made. The average slope of the banks is about 45°. A pipe is stuck through the curb on the low side of the pond as a means of removing the clear solution that accumulates. This solution carries low values, and an artificial dam is now being built with tailing, behind which this run-off will later be impounded, concentrated by evaporation, and then returned to the mill.

From one to three ponds usually are being carried up, at least two being kept in workable condition as a reserve during wet or freezing weather. Experience is an important factor in this system of impounding; if the pond is too large cracks will develop, followed by fast cutting washouts, or if the pond is too small or is carried up too fast, slips will occur in the banks. Many areas of the tailing pile are now 60 feet in depth. The elevation of the new tailing thickener will permit gravity storage of an additional 35 feet over all early tailing. One man, with some occasional help, takes care of the tailing disposal.

A crust, which is the product of evaporation and capillary attraction, forms on the surface of the tailing piles from time to time. The amount of gold in the solution tailing has been reduced considerably in recent years, so that this crust is not enriched nearly as much as in former years. It averages about $10 per ton, so is occasionally scraped, on a lease basis, and returned to the mill as custom ore. As the product requires no grinding, and as its valuable content is water soluble, it takes a low treatment rate.

SAMPLING

Treatment Plant

Routine samples of pulp are taken by hand at hourly intervals of no. 1 agitator feed, no. 4 agitator discharge, and the tailing stream. Due to the fineness of grinding and the high solids content at these points, there is no segregation of sizes and launder drops for sampling are not provided. A few c.c. of permanganate of potash solution is put in the sample bucket to prevent any dissolving action after the sample is cut. These samples are washed thoroughly in a pressure filter at end of 24-hour periods, dried, and sent to the assay office.

Solution samples are taken as follows: Drip samples of precipitation heads and tails are taken up at 8-hour intervals. Hand-cut samples are taken at the overflows of the two thickeners at the head of the decantation plant and of the tailing thickener; they are taken up at 24-hour intervals. The decantation-plant samples serve as checks on the wash balance of the parallel decanters as well as indicate the trend of solution values to precipitation; the last is the value of solution being discharged to the tailing pile.

It has been determined that the difference, if any, between solution values in the tailing-thickener overflow and underflow cannot be determined by assay. The overflow assay, therefore, is used in calculating the daily solution value in mill tailing. Specific-gravity determinations of ball-mill discharges, classifier overflows, and of all thickener underflows are made and recorded at regular intervals. The liquid-to-solid ratio of daily mill tailing is determined by averaging the specific gravities; the daily tailing loss is the sum of the separate tonnages multiplied by the respective assay values. A daily 24-hour sample of the primary thickener underflow is also taken for screen test. The sum of the gold in the tailing and the net value of the bullion retained in presses is considered the mill head for the daily mill record. A portion of the daily washed tailing sample is retained without being pulverized; it is composited daily on the basis of tonnage milled. The solution tailing is composited in like manner. These are rather large samples by the end of each month; they are assayed very carefully for gold and silver by several fusions and cupellations of each. A careful screen analysis, with assay of sizes, is also made on the pulp sample.

Tailing composite assays and mint returns are the bases of monthly reports. These do not account for slag or other absorption, such as cutting in additional tankage, with its accompanying tie-up of values. It is intended in the future to clean up all scoop boxes and classifier sand beds, in addition to marketing slag, for a metallurgical check against the sampling mill before the end of each fiscal year. Indications are that there is a tie-up of approximately 1 percent in the scoop boxes and sand beds.

Handling of Control Samples

Samples containing excess moisture are riffled for a moisture sample and then dried as a guard against pancaking when being put through the hand-fed rolls. Two 10-pound samples from each lot of ore are riffled by hand on a Jones divider; one sample is sacked and held at the mill as a reserve and the other is sent to the assay office for moisture determination and further preparation. Samples riffled at night are placed in a pan, the latter then being returned to the can containing its original moist reject. This, in turn, is covered, as a guard against moisture loss, until morning.

In cases of small odd lots, the entire lot is either run through the sampling mill or the third cutter is stopped, in which case only two automatic cuts are made, and the final sample is ample for further working. Size of shipment governs choice of these two alternatives.

Assay office procedure is as follows: The sample is dried thoroughly and the moisture recorded; it is then pulverized in a Braun pulverizer and further ground in a porcelain mortar to pass through a 100-mesh sieve. It is then rolled for 30 minutes. In the case of calcitic ores, which tend to agglomerate in the rolling process, the sample, after 15 minutes rolling, is put through a 30-mesh sieve in order to break up the agglomerations, and then rolling is continued. The rolled sample is spread out in a thin layer over a 30-inch circle. Small dips are then taken with a 5-inch spatula over the entire surface at about 1-inch intervals for one control. Successive controls are the product of staggering dips between the previous ones.

Six controls are prepared for each lot of ore, one for the shipper, one for the buyer, and a third for a possible umpire. The remaining controls are held for a possible dispute. Umpires are sent to several reputable western firms, the shipper having his choice.

Settlement is made on the basis of dry tonnage, silver at domestic price and gold at $35 per ounce. Control assays for silver are made only on known silver-bearing ores carrying 2 ounces or more. Milling rates and settlement schedules are given under "Custom-Mill Schedules."

During the 20 months a weightometer has been in operation, an exact record has been kept of ore settlements, based upon weightometer and sampling-mill records, as compared with the record of bullion plus tails. Over that period, the assay value of ores by the sampler was $1,855,907.11 in gold; the value by bullion plus the gold in the tails was $1,835,116.51 in gold. This value (of bullion plus tails) is 98.88 percent of the assay value by the sampling mill.

Considering that since the weightometer was installed there has been an estimated $2,500 additional tie-up of values in the new agitator, it will be seen that the addition of this value to bullion plus tails would raise the total to 99.01 percent of the sampling mill value. The difference of 0.99 percent can probably be accounted for by natural absorption throughout the entire plant, exclusive of the classifier and scoop box beds, which are cleaned at the end of each fiscal year and do not enter into the absorption figures.

ORE-TESTING LABORATORY

Although most of the custom ore received at the mill originates in the Oatman District, certain of these ores will yield a satisfactory tailing with a coarser grind than will others. Other ores, including concentrates from concentration mills, are offered, some being accepted. Settlements are made on silver, also, provided the content is 2 ounces or more. In order to check the amenability of the outside ores to treatment under the customary milling conditions, as well as to determine the grinding requirements of all ores, the mill was equipped with laboratory testing apparatus early in 1934. This apparatus consists of a Braun-Welch batch-grinding mill and rolls for turning several 5-pound reagent bottles, in which usual agitation tests are made, and a high-speed spindle-type agitator for cyanide testing. There is also the usual accessory equipment, including a 500-gram Denver Equipment Co. flotation test machine. This equipment has been the source of much interesting information and is a safeguard against the receipt of refractory ores. A representative sample is requested before any strange ore is accepted. The posted milling rates and settlement schedules apply to the free milling ores of the local district and to others that are amenable to treatment at the plant.

POWER

Power is furnished by the Citizen's Utility Co. of Kingman. The current requirements of the Tom Reed place the company on a 1-3/4 cents per kw. hr. rating. Power consumption per ton of ore milled during 1934-36 was 32.68, 30.10, and 28.31 kw. hrs., respectively.

METALLURGICAL DATA

The following tabulation gives the tonnage treated and other metallurgical data for the fiscal years 1934-36:

Fiscal year	Tons milled	Mill heads		Mill tails		Extraction, percent	
		Gold 1/	Silver 2/	Gold 1/	Silver 2/	Gold	Silver
1934	58,791.47	$11.408		$0.549		95.19	
3/1935	68,610.96	12.605	$0.588	0.675	$0.232	94.65	60.55
1936	91,310.65	12.370	0.460	0.780	0.155	93.69	66.30

1/ Gold at $35.
2/ Silver at 77.57 cents.
3/ Strike conditions caused 56-day shutdown.

Consumption of major supplies, October 1936, 9,053.22 tons milled

Item	Pounds per ton of ore milled
Grinding balls, 5-inch	1.66
Grinding balls, 2-1/2 inch	1.85
Aerobrand cyanide, 25 to 27 percent cyanogen	1.75
Lime	4.07
Zinc dust (Merrillite)	0.46

COSTS

The following tabulation gives the milling costs for the period 1934-36:

Year	Superintendence	Labor	Power	Misc. supplies and expense 1/	Equipment repair	Total
1934	$0.049	$0.310	$0.572	$0.611	$0.166	$1.718
1935	.056	.328	.527	.551	.232	1.694
1936	.052	.361	.495	.544	.137	1.589

1/ Includes industrial insurance.

The cost of major supplies per ton was

Balls	$0.099
Cyanide	.157
Liners	.069 (at $0.09 per pound)
Lime	.025
Zinc	.052